3 Physics & Engineering

Program Library

Astronomy
Statics & Dynamics
Relativity
Mechanics
Properties of Matter
Fluids
Structures
Thermodynamics

Sinclair Cambridge Programmable

Printed by Hobsons Press (Cambridge) Ltd

Physics & Engineering

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CONTENTS

How to use these programs

Each program is arranged as follows:

1. On the left of the page, explanatory information and the 'execution sequence', the sequence of keystrokes necessary for running the program. Results displayed are printed in gold.
2. In the first column on the right hand side of the page, the sequence of keystrokes which make up the program.
3. In the second and third columns on the right hand side of the page, the program in check symbol and step number form (see section on checking the program).

Notes

1. Where a key has more than one function, the relevant function is printed as the keystroke in the first column

   e.g. the keystroke [8] (cos / arccos) may appear as 8, cos or arccos.
2. The symbol ▾ within a program always refers to the key [•/EE/–] (▾)
3. The symbol # refers to [3] (ChN/#)
4. The abbreviation gin is 'go if neg' and so refers to the key [1] (go if neg)

Entering the program

To enter a program into the calculator:

1.	Press [▲▼] [▲▼] [2] (go to) [0] [0]	Display shows step programmed at 00 in check symbol form as described below.
2.	Press [▲▼] [RUN] (learn)	No change in display.
3.	Press the sequence of keys for the program as shown in the first column of the program page.	At each stage the step about to be overwritten is displayed. When the machine is first switched on every step is zero.
4.	Press [C/CE]	Normal number display is resumed.
5.	Press [▲▼] [▲▼] [2] (go to) [0] [0]	The step programmed at 00 will be displayed.

Checking the program

Each of the programs in the library is shown in check symbol form in the second column on the right-hand side of the page.

Press [▲▼] [C/CE] (step) repeatedly, and at each stage the check symbol will appear on the left of the display with the step number on the right. Ignore the four zeros in the display.

e.g. A.0000 03

(check symbol) (step number)

After stepping through the program, press

[▲▼] [▲▼] [2] (go to) [0] [0] before execution.

Finally, press [C/CE] and the program is ready for use.

Correcting the program

If the check symbol for a particular step number is not as indicated in the last two columns of the program page:

1. Press [▲▼] [▲▼] [2] (go to)

   followed by the step number if the appropriate step number is not already displayed.

2. Press [▲▼] [RUN] (learn)
3. Enter the correct keystroke. The display will then show the next step in the program. If this is also incorrect, enter the correct keystroke. At each stage, the step about to be overwritten will be displayed.
4. When correction has been completed, press [C/CE]. Any step which has not been overwritten will not be affected.
5. Press [▲▼] [▲▼] [2] (go to) [0] [0]

Note

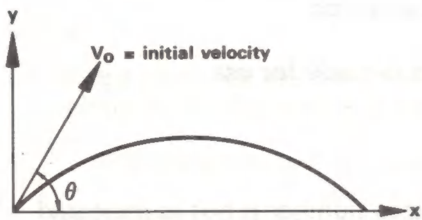
To restore normal use of the calculator after entering or checking the program, press [C/CE]

Running the program

Press the sequence of keys as shown in the program library in the execution sequence. Results displayed are printed in gold.

PROJECTILES

Position relative to point of projection after time t



$x = v_o t \cos \theta$

$y = v_o t \sin \theta - \frac{gt^2}{2}$

Execution:

θ° / RUN / v_o / RUN / t / RUN / x / RUN / y

In S.I. units; g taken as $9{\cdot}81 ms^{-2}$.

▼	A	00
D→R	3	01
sto	2	02
tan	9	03
X	·	04
(	6	05
rcl	5	06
cos	8	07
X	·	08
stop	0	09
X	·	10
stop	0	11
sto	2	12
)	6	13
stop	0	14
–	F	15
(	6	16
rcl	5	17
X	·	18
X	·	19
#	3	20
4	4	21
·	A	22
9	9	23
0	0	24
5	5	25
=	–	26
)	6	27
=	–	28
stop	0	29
▼	A	30
goto	2	31
0	0	32
0	0	33
		34
		35

PROJECTILES

Range, maximum height and time of flight

▼	A	00
D→R	3	01
sto	2	02
sin	7	03
X	·	04
stop	0	05
X	·	06
#	3	07
·	A	08
2	2	09
0	0	10
4	4	11
X	·	12
stop	0	13
X	·	14
#	3	15
1	1	16
·	A	17
2	2	18
2	2	19
6	6	20
÷	G	21
stop	0	22
(	6	23
rcl	5	24
tan	9	25
)	6	26
+	E	27
+	E	28
=	–	29
stop	0	30
▼	A	31
goto	2	32
0	0	33
0	0	34
		35

$$T = \frac{2v_o}{g} \sin\theta$$

$$R = \frac{2v_o^2}{g} \sin\theta \cos\theta$$

$$H = \frac{v_o^2}{2g} \sin^2\theta$$

Execution:

$\theta°$ / RUN / v_o / RUN / time of flight / RUN / maximum height / RUN / range

In S.I. units; g taken as $9{\cdot}81 ms^{-2}$.

PROJECTILES

Necessary angle of projection for given range with given speed of projection

$\sin 2\alpha = \frac{Rg}{v^2}$ giving two possible angles α_1 and α_2.

Execution:

v / RUN / R / RUN / α_1° / RUN / α_2°

In S.I. units; g taken as $9{\cdot}81\,ms^{-2}$.

X	·	00
÷	G	01
X	·	02
#	3	03
9	9	04
·	A	05
8	8	06
1	1	07
X	·	08
stop	0	09
=	–	10
▼	A	11
arcsin	7	12
▼	A	13
R→D	3	14
÷	G	15
#	3	16
2	2	17
–	F	18
stop	0	19
#	3	20
9	9	21
0	0	22
–	F	23
=	–	24
stop	0	25
▼	A	26
goto	2	27
0	0	28
0	0	29
		30
		31
		32
		33
		34
		35

PARALLELOGRAM LAW FOR FORCES

$R = \sqrt{P^2 + Q^2 + 2PQ \cos \alpha}$

Execution:

P / RUN / Q / RUN / $\alpha°$ / RUN / R

Range: $0 \leqslant \alpha° \leqslant 180°$

E may appear if α is close to 0° or 180°

sto	2	00
stop	0	01
X	·	02
(	6	03
+	E	04
rcl	5	05
=	–	06
▼	A	07
MEx	5	08
)	6	09
X	·	10
(	6	11
stop	0	12
–	F	13
#	3	14
9	9	15
0	0	16
–	F	17
=	–	18
▼	A	19
D→R	3	20
sin	7	21
–	F	22
#	3	23
1	1	24
+	E	25
)	6	26
+	E	27
(	6	28
rcl	5	29
X	·	30
)	6	31
=	–	32
$\sqrt{x}$	1	33
stop	0	34
=	–	35

CONSTANT ACCELERATION MOTION

u = initial velocity
v = final velocity
s = distance covered
f = acceleration
t = time

$v = u + ft$

$$s = ut + \frac{ft^2}{2}$$

Execution:

t / RUN / f / RUN / u / RUN / v /RUN / s

X	·	00
(	6	01
X	·	02
stop	0	03
÷	G	04
#	3	05
2	2	06
+	E	07
sto	2	08
+	E	09
stop	0	10
–	F	11
stop	0	12
rcl	5	13
)	6	14
=	–	15
stop	0	16
▼	A	17
goto	2	18
0	0	19
0	0	20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

CONSTANT ACCELERATION MOTION

For notation see page 12

$v = \sqrt{u^2 + 2fs}$

Execution:

u / RUN / f / RUN / s / RUN / v

This gives the absolute value of v; other considerations must be used to determine the correct sign.

X	·	00
+	E	01
(	6	02
stop	0	03
X	·	04
stop	0	05
+	E	06
)	6	07
=	–	08
$\sqrt{x}$	1	09
stop	0	10
▼	A	11
goto	2	12
0	0	13
0	0	14
		15
		16
		17
		18
		19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

CONSTANT ACCELERATION MOTION

For notation see page 12

(i) $t = \dfrac{v - u}{f}$

$s = \dfrac{v^2 - u^2}{2f}$

Execution:

v / RUN / u / RUN / f / RUN / t / RUN / s

(ii) $f = \dfrac{v - u}{t}$

Execution:

v / RUN / u / RUN / t / RUN / f / RUN

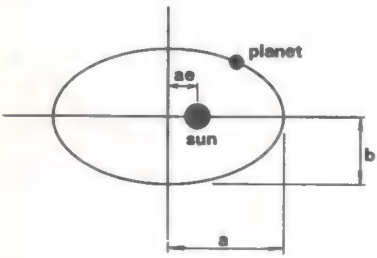
(iii) $f = \dfrac{v^2 - u^2}{2s}$

Execution:

v / RUN / u / RUN / s / RUN / RUN / f

–	F	00
stop	0	01
sto	2	02
÷	G	03
(	6	04
÷	G	05
#	3	06
2	2	07
+	E	08
rcl	5	09
=	–	10
sto	2	11
stop	0	12
)	6	13
X	·	14
stop	0	15
rcl	5	16
=	–	17
stop	0	18
▼	A	19
goto	2	20
0	0	21
0	0	22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

PLANETARY MOTION



Kepler's law:
orbit is an ellipse with sun at one focus.

$$r = \frac{p}{1 + e\cos\theta} = \frac{b\sqrt{1-e^2}}{1 + e\cos\theta} = \frac{b^2}{a(1 + e\cos\theta)}\,;$$

$$e^2 = 1 - \frac{b^2}{a^2}$$

Execution:

$\theta°$ / RUN / e / RUN / p / RUN / r

X	·	00
=	–	01
$\sqrt{x}$	1	02
–	F	03
#	3	04
9	9	05
0	0	06
–	F	07
=	–	08
▼	A	09
D→R	3	10
sin	7	11
X	·	12
stop	0	13
+	E	14
#	3	15
1	1	16
÷	G	17
X	·	18
stop	0	19
=	–	20
stop	0	21
▼	A	22
goto	2	23
0	0	24
0	0	25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

PLANETARY MOTION

For notation see page 15

Execution:

$\theta°$ / RUN / e / RUN / b / RUN /

X	·	00
=	–	01
$\sqrt{x}$	1	02
–	F	03
#	3	04
9	9	05
0	0	06
–	F	07
=	–	08
▼	A	09
D→R	3	10
sin	7	11
X	·	12
stop	0	13
sto	2	14
+	E	15
#	3	16
1	1	17
÷	G	18
X	·	19
(	6	20
rcl	5	21
X	·	22
–	F	23
+	E	24
#	3	25
1	1	26
=	–	27
$\sqrt{x}$	1	28
)	6	29
X	·	30
stop	0	31
=	–	32
stop	0	33
=	–	34
=	–	35

PLANETARY MOTION

For notation see page 15

Execution:

b / RUN / a / RUN / $\theta°$ / RUN / [illegible]

sto	2	00
÷	G	01
stop	0	02
X	·	03
▼	A	04
MEx	5	05
=	–	06
▼	A	07
MEx	5	08
▼	A	09
arcsin	7	10
cos	8	11
X	·	12
(	6	13
stop	0	14
X	·	15
=	–	16
$\sqrt{x}$	1	17
–	F	18
#	3	19
9	9	20
0	0	21
–	F	22
=	–	23
▼	A	24
D→R	3	25
sin	7	26
)	6	27
+	E	28
#	3	29
1	1	30
÷	G	31
rcl	5	32
÷	G	33
=	–	34
stop	0	35

DOPPLER EFFECT (non-relativistic)

For sound waves, etc.

v_o = observer velocity
v_s = source velocity
f_s = transmitted frequency
f_o = observed frequency
c = velocity of wave

Given observed frequency, to find transmitted frequency.

$$f_s = \left(\frac{c + v_o}{c - v_s}\right) f_o$$

Execution:

c / RUN / v_o / RUN / v_s / RUN / f_o / RUN / f_s

sto	2	00
+	E	01
stop	0	02
÷	G	03
(	6	04
rcl	5	05
−	F	06
stop	0	07
)	6	08
X	·	09
stop	0	10
=	−	11
stop	0	12
▼	A	13
goto	2	14
0	0	15
0	0	16
		17
		18
		19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

DOPPLER EFFECT
(non-relativistic)

For notation see page 18

Given transmitted frequency, to find observed frequency.

Execution:

c / RUN / v_s / RUN / v_o / RUN / f_s / RUN / f_o

sto	2	00
—	F	01
stop	0	02
÷	G	03
(	6	04
stop	0	05
+	E	06
rcl	5	07
)	6	08
X	·	09
stop	0	10
=	—	11
stop	0	12
▼	A	13
goto	2	14
0	0	15
0	0	16
		17
		18
		19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

DOPPLER EFFECT
(non-relativistic)

–	F	00
(	6	01
+	E	02
stop	0	03
X	·	04
stop	0	05
÷	G	06
stop	0	07
)	6	08
=	–	09
stop	0	10
▼	A	11
goto	2	12
0	0	13
0	0	14
		15
		16
		17
		18
		19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

For notation see page 18

Given both frequencies, to find source velocity.

Execution:

c / RUN / v_o / RUN / f_o / RUN / f_s / RUN / v_s

DOPPLER EFFECT (relativistic)

(Red shift or blue shift)

f_s = source frequency
f_o = observed frequency
c = speed of light = $2{\cdot}997925 \times 10^8 ms^{-1}$
v = speed of source
θ = direction of motion of source relative to observer

$$f_o = f_s \frac{\sqrt{1 - \frac{v^2}{c^2}}}{1 - \frac{v}{c}\cos\theta}$$

Execution:

(i) v / RUN / c / RUN / θ / RUN / f_s / X / RUN / f_o

(ii) v / RUN / c / RUN / θ / RUN / f_o / ÷ / RUN / f_s

÷	G	00
stop	0	01
X	·	02
sto	2	03
(	6	04
stop	0	05
X	·	06
=	–	07
$\sqrt{x}$	1	08
–	F	09
#	3	10
9	9	11
0	0	12
=	–	13
▼	A	14
D→R	3	15
sin	7	16
)	6	17
+	E	18
#	3	19
1	1	20
÷	G	21
X	·	22
(	6	23
rcl	5	24
▼	A	25
arcsin	7	26
cos	8	27
)	6	28
=	–	29
sto	2	30
stop	0	31
rcl	5	32
=	–	33
stop	0	34
=	–	35

DOPPLER EFFECT (relativistic)

(Red shift or blue shift)

Source receding from observer at velocity v. Source frequency f_s, observed frequency f_o.

$$f_o = f_s \frac{\sqrt{1 - \frac{v^2}{c^2}}}{1 + \frac{v}{c}} = f_s \sqrt{\frac{1 - \frac{v}{c}}{1 + \frac{v}{c}}}$$

Given v and one frequency, to find the other frequency.

Execution:

(i) v / RUN / c / RUN / f_s / X / RUN / f_o

(ii) v / RUN / c / RUN / f_o / ÷ / RUN / f_s

÷	G	00
stop	0	01
–	F	02
#	3	03
1	1	04
÷	G	05
(	6	06
+	E	07
#	3	08
2	2	09
–	F	10
)	6	11
=	–	12
$\sqrt{x}$	1	13
sto	2	14
stop	0	15
rcl	5	16
=	–	17
stop	0	18
▼	A	19
goto	2	20
0	0	21
0	0	22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

DOPPLER EFFECT (relativistic)

(Red shift or blue shift)

To find v, given f_o and f_s.

Execution:

f_o / RUN / f_s / RUN / c / RUN / [illegible]

If the wavelengths λ_o and λ_s are known:

Execution:

λ_s/ RUN / λ_o / RUN / c / RUN / v

If v is negative, motion is towards observer.

÷	G	00
stop	0	01
X	·	02
–	F	03
#	3	04
1	1	05
÷	G	06
(	6	07
+	E	08
#	3	09
2	2	10
–	F	11
)	6	12
X	·	13
stop	0	14
=	–	15
stop	0	16
▼	A	17
goto	2	18
0	0	19
0	0	20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

RELATIVITY

Fitzgerald contraction, time dilation and mass change.

$$T' = T\left(1 - \frac{v^2}{c^2}\right)^{½}$$

$$L' = L\left(1 - \frac{v^2}{c^2}\right)^{½}$$

$$M' = M\left(1 - \frac{v^2}{c^2}\right)^{-½}$$

Execution:

(i) v / RUN / c / RUN / T / X / RUN / T'

(ii) v / RUN / c / RUN / L / X / RUN / L'

(iii) v / RUN / c / RUN / M / ÷ / RUN / M'

÷	G	00
stop	0	01
X	·	02
–	F	03
+	E	04
#	3	05
1	1	06
=	–	07
$\sqrt{x}$	1	08
sto	2	09
stop	0	10
rcl	5	11
=	–	12
stop	0	13
▼	A	14
goto	2	15
0	0	16
0	0	17
		18
		19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

LORENTZ TRANSFORMATION

(i) $$X' = \frac{X - \beta c T}{\sqrt{1 - \beta^2}}$$

(ii) $$T' = \frac{T - \dfrac{\beta X}{c}}{\sqrt{1 - \beta^2}}$$

where $\beta = \dfrac{v}{c}$

(a) Units such that c = 1

Execution:

(i) β / RUN / X / RUN / T / RUN / X′

(ii) β / RUN / T / RUN / X / RUN / T′

(b) Any consistent units

Execution:

(i) v / ÷ / c / = / RUN / X / RUN / T / X / c / RUN / X′

(ii) v / ÷ / c / = / RUN / T / RUN / X / ÷ / c / RUN / T′

▼	A	00
arcsin	7	01
sto	2	02
cos	8	03
÷	G	04
X	·	05
stop	0	06
–	F	07
(	6	08
rcl	5	09
tan	9	10
X	·	11
stop	0	12
)	6	13
=	–	14
stop	0	15
▼	A	16
goto	2	17
0	0	18
0	0	19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

COMPOUND PENDULUM

T = period
k_o = radius of gyration about pivot
k_g = radius of gyration about c.g.
r = distance from pivot to c.g.
l = length of simple equivalent pendulum

$$T = \frac{2\pi k_o}{\sqrt{gr}} \qquad l = \frac{k_o^2}{r}$$

Execution:

r / RUN / k_o / RUN / T / RUN / l

In S.I. units; g taken as $9{\cdot}81 ms^{-2}$.

$\sqrt{x}$	1	00
÷	G	01
X	·	02
stop	0	03
X	·	04
sto	2	05
#	3	06
2	2	07
·	A	08
0	0	09
0	0	10
6	6	11
1	1	12
=	–	13
stop	0	14
rcl	5	15
X	·	16
=	–	17
stop	0	18
▼	A	19
goto	2	20
0	0	21
0	0	22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

COMPOUND PENDULUM

Notation as on page 26

Use $k_o = \sqrt{k_g^2 + r^2}$

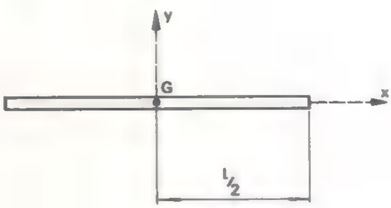
Execution:

r / RUN / k_g / RUN / T / RUN / l

sto	2	00
X	·	01
+	E	02
(	6	03
stop	0	04
X	·	05
)	6	06
÷	G	07
rcl	5	08
=	–	09
sto	2	10
$\sqrt{x}$	1	11
X	·	12
#	3	13
2	2	14
·	A	15
0	0	16
0	0	17
6	6	18
1	1	19
=	–	20
stop	0	21
rcl	5	22
stop	0	23
▼	A	24
goto	2	25
0	0	26
0	0	27
		28
		29
		30
		31
		32
		33
		34
		35

CENTRE OF GRAVITY AND RADIUS OF GYRATION

Straight Rod



$k^2_{xx} = 0$

$$k^2_{yy} = \frac{l^2}{12}$$

Execution:

l / RUN / k^2_{yy}

Notation throughout this section:

G = position of centre of gravity
k_{xx} = radius of gyration about x-axis through G
k_{yy} = radius of gyration about y-axis through G

X	·	00
÷	G	01
#	3	02
1	1	03
2	2	04
=	—	05
stop	0	06
▼	A	07
goto	2	08
0	0	09
0	0	10
		11
		12
		13
		14
		15
		16
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		18
		19
		20
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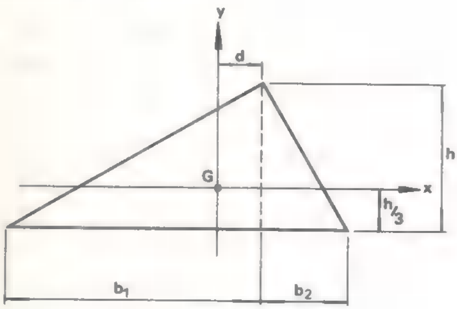
CENTRE OF GRAVITY AND RADIUS OF GYRATION

Triangular Lamina



For notation see page 28

$$d = \frac{b_1 - b_2}{3}$$

$$k_{xx}^2 = \frac{h^2}{18}$$

$$k_{yy}^2 = \frac{b_1^2 + b_1 b_2 + b_2^2}{18}$$

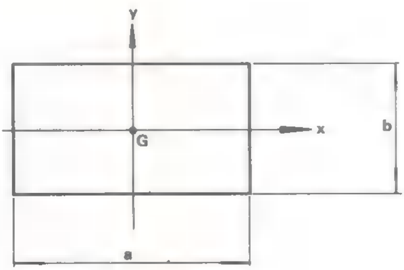
Execution:

b_1 / RUN / b_2 / RUN / d / RUN / k_{yy}^2 / h / RUN / k_{xx}^2

X	·	00
(	6	01
–	F	02
stop	0	03
sto	2	04
÷	G	05
#	3	06
3	3	07
X	·	08
stop	0	09
÷	G	10
#	3	11
2	2	12
=	–	13
▼	A	14
MEx	5	15
)	6	16
÷	G	17
#	3	18
6	6	19
+	E	20
rcl	5	21
=	–	22
stop	0	23
X	·	24
÷	G	25
#	3	26
1	1	27
8	8	28
=	–	29
stop	0	30
▼	A	31
goto	2	32
0	0	33
0	0	34
		35

CENTRE OF GRAVITY AND RADIUS OF GYRATION

Rectangular lamina



For notation see page 28

$$k^2_{xx} = \frac{b^2}{12}$$

$$k^2_{yy} = \frac{a^2}{12}$$

Execution:

b / RUN / k^2_{xx} / a / RUN / k^2_{yy}

X	·	00
÷	G	01
#	3	02
1	1	03
2	2	04
=	–	05
stop	0	06
▼	A	07
goto	2	08
0	0	09
0	0	10
		11
		12
		13
		14
		15
		16
		17
		18
		19
		20
		21
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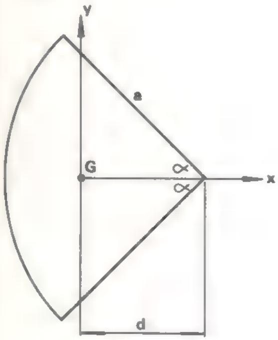
CENTRE OF GRAVITY AND RADIUS OF GYRATION

Sector of circular lamina



For notation see page 28

$$d = \frac{2a \sin \alpha}{3\alpha}$$

$$k_{xx}^2 = \frac{a^2}{4}\left(1 - \frac{\sin 2\alpha}{2\alpha}\right)$$

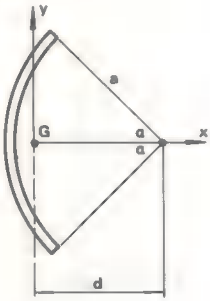
Execution:

α (in radians) / RUN / a / RUN / d
RUN / k_{xx}^2

sto	2	00
sin	7	01
÷	G	02
rcl	5	03
=	–	04
▼	A	05
MEx	5	06
cos	8	07
X	·	08
(	6	09
stop	0	10
÷	G	11
#	3	12
3	3	13
+	E	14
X	·	15
▼	A	16
MEx	5	17
=	–	18
stop	0	19
)	6	20
–	F	21
rcl	5	22
X	·	23
rcl	5	24
–	F	25
X	·	26
#	3	27
9	9	28
÷	G	29
#	3	30
1	1	31
6	6	32
=	–	33
stop	0	34
=	–	35

CENTRE OF GRAVITY AND RADIUS OF GYRATION

Curved rod (arc of a circle)



▼	A	00
D→R	3	01
sto	2	02
sin	7	03
÷	G	04
rcl	5	05
=	—	06
▼	A	07
MEx	5	08
cos	8	09
X	·	10
(	6	11
stop	0	12
X	·	13
▼	A	14
MEx	5	15
)	6	16
stop	0	17
—	F	18
rcl	5	19
X	·	20
rcl	5	21
—	F	22
÷	G	23
#	3	24
2	2	25
=	—	26
stop	0	27
▼	A	28
goto	2	29
0	0	30
0	0	31
		32
		33
		34
		35

For notation see page 28

$$d = a \frac{\sin \alpha}{\alpha}$$

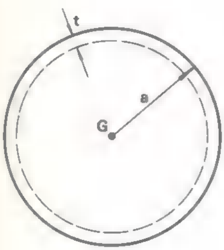
$$k_{xx}^2 = \frac{a^2}{2} \left(1 - \frac{\sin 2\alpha}{2\alpha} \right)$$

Execution:

α° / RUN / a / RUN / d / RUN / k_{xx}^2

CENTRE OF GRAVITY AND RADIUS OF GYRATION

Spherical shell



For notation see page 28

a = radius
t = thickness

Volume = $4\pi a^2 t$

$$k_{xx}^2 = k_{yy}^2 = k_{zz}^2 = \frac{2a^2}{3}$$

Execution:

a / RUN / k_{xx}^2 / t / RUN / volume

X	·	00
÷	G	01
#	3	02
1	1	03
·	A	04
5	5	05
X	·	06
stop	0	07
X	·	08
#	3	09
1	1	10
0	0	11
8	8	12
0	0	13
=	—	14
▼	A	15
D→R	3	16
stop	0	17
▼	A	18
goto	2	19
0	0	20
0	0	21
		22
		23
		24
		25
		26
		27
		28
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		34
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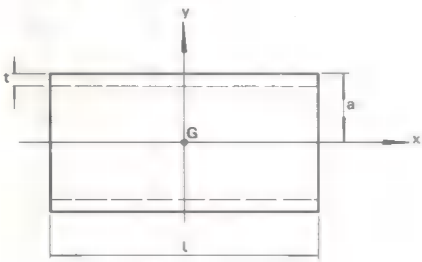
CENTRE OF GRAVITY AND RADIUS OF GYRATION

Thin-walled tube



For notation see page 28

a = radius
l = length
t = thickness

Volume = $2\pi alt$

$k^2_{xx} = a^2$

$$k^2_{yy} = k^2_{zz} = \frac{a^2}{2} + \frac{l^2}{12}$$

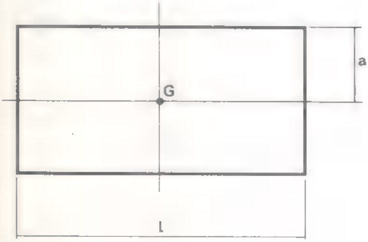
Execution:

l / RUN / a / RUN / t / RUN / volume / RUN / k^2_{xx} / RUN / k^2_{yy}

X	·	00
+	E	01
(	6	02
$\sqrt{x}$	1	03
X	·	04
stop	0	05
sto	2	06
X	·	07
stop	0	08
X	·	09
#	3	10
3	3	11
6	6	12
0	0	13
=	—	14
▼	A	15
D→R	3	16
stop	0	17
rcl	5	18
X	·	19
X	·	20
stop	0	21
#	3	22
6	6	23
=	—	24
)	6	25
÷	G	26
#	3	27
1	1	28
2	2	29
=	—	30
stop	0	31
=	—	32
=	—	33
=	—	34
=	—	35

CENTRE OF GRAVITY AND RADIUS OF GYRATION

Solid cylinder



For notation see page 28

a = radius
l = length

Volume = $\pi a^2 l$

$$k^2_{xx} = \frac{a^2}{2}$$

$$k^2_{yy} = \frac{a^2}{4} + \frac{l^2}{12} = k^2_{zz}$$

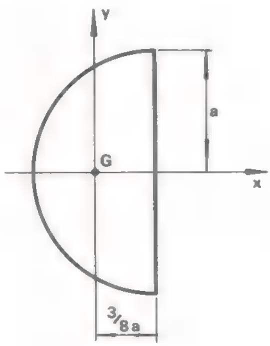
Execution:

a / RUN / k^2_{xx} / l / RUN / volume / RUN / k^2_{yy}

X	·	00
÷	G	01
#	3	02
2	2	03
+	E	04
(	6	05
X	·	06
stop	0	07
sto	2	08
X	·	09
#	3	10
3	3	11
6	6	12
0	0	13
=	—	14
▼	A	15
D→R	3	16
stop	0	17
rcl	5	18
X	·	19
÷	G	20
#	3	21
6	6	22
=	—	23
)	6	24
÷	G	25
#	3	26
2	2	27
=	—	28
stop	0	29
▼	A	30
goto	2	31
0	0	32
0	0	33
		34
		35

CENTRE OF GRAVITY AND RADIUS OF GYRATION

Solid hemisphere



For notation see page 28

$$\text{Volume} = \frac{2\pi a^3}{3}$$

$$k_{xx}^2 = \frac{2a^2}{5}$$

$$k_{yy}^2 = \frac{83a^2}{320}$$

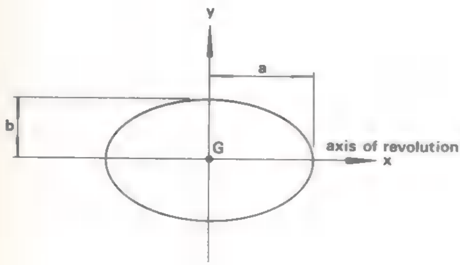
Execution:

a / RUN / volume / RUN / k_{xx}^2 / RUN / k_{yy}^2

sto	2	00
X	·	01
X	·	02
(	6	03
X	·	04
rcl	5	05
X	·	06
#	3	07
1	1	08
2	2	09
0	0	10
=	–	11
▼	A	12
D→R	3	13
stop	0	14
#	3	15
·	A	16
4	4	17
=	–	18
)	6	19
X	·	20
stop	0	21
#	3	22
8	8	23
3	3	24
÷	G	25
#	3	26
1	1	27
2	2	28
8	8	29
=	–	30
stop	0	31
=	–	32
=	–	33
=	–	34
=	–	35

CENTRE OF GRAVITY AND RADIUS OF GYRATION

Solid spheroid



For notation see page 28

(For sphere, a = b)

$$\text{Volume} = \frac{4\pi ab^2}{3}$$

$$k_{xx}^2 = \frac{2b^2}{5}$$

$$k_{yy}^2 = \frac{a^2 + b^2}{5}$$

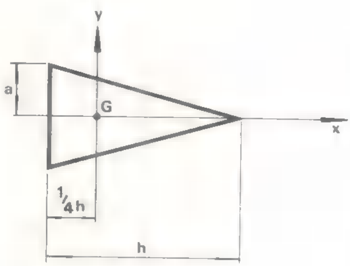
Execution:

b / RUN / [illegible] / a / RUN / volume / RUN / k_{yy}^2

X	·	00
X	·	01
#	3	02
·	A	03
4	4	04
+	E	05
(	6	06
X	·	07
stop	0	08
sto	2	09
X	·	10
#	3	11
6	6	12
0	0	13
0	0	14
=	–	15
▼	A	16
D→R	3	17
stop	0	18
rcl	5	19
X	·	20
X	·	21
#	3	22
·	A	23
4	4	24
=	–	25
)	6	26
÷	G	27
#	3	28
2	2	29
=	–	30
stop	0	31
=	–	32
=	–	33
=	–	34
=	–	35

CENTRE OF GRAVITY AND RADIUS OF GYRATION

Solid cone



For notation see page 28

h = height
a = radius of base

$$\text{Volume} = \frac{\pi a^2 h}{3}$$

$$k^2_{xx} = \frac{3a^2}{10}$$

$$k^2_{yy} = \frac{3(4a^2 + h^2)}{80}$$

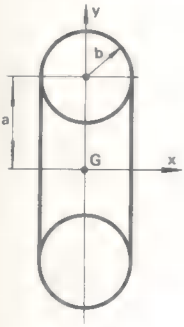
Execution:

a / RUN / k^2_{xx} / h / RUN / volume / RUN / k^2_{yy}

X	·	00
X	·	01
#	3	02
·	A	03
3	3	04
+	E	05
(	6	06
X	·	07
stop	0	08
sto	2	09
X	·	10
#	3	11
2	2	12
0	0	13
0	0	14
=	–	15
▼	A	16
D→R	3	17
stop	0	18
rcl	5	19
X	·	20
#	3	21
·	A	22
0	0	23
7	7	24
5	5	25
=	–	26
)	6	27
÷	G	28
#	3	29
2	2	30
=	–	31
stop	0	32
=	–	33
=	–	34
=	–	35

CENTRE OF GRAVITY AND RADIUS OF GYRATION

Toroid (circular section)



For notation see page 28

Volume = $2\pi^2ab^2$

$$k_{xx}^2 = a^2 + \frac{3b^2}{4}$$

$$k_{yy}^2 = \frac{a^2}{2} + \frac{5b^2}{8}$$

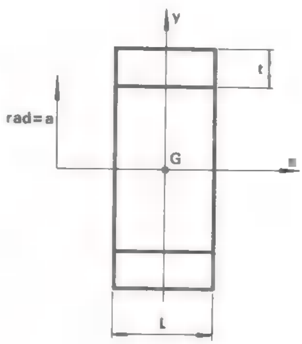
Execution:

b / RUN / a / RUN / volume / RUN / k_{xx}^2 / RUN / k_{yy}^2

X	·	00
÷	G	01
#	3	02
4	4	03
=	–	04
sto	2	05
stop	0	06
X	·	07
+	E	08
(	6	09
$\sqrt{x}$	1	10
X	·	11
rcl	5	12
X	·	13
#	3	14
7	7	15
8	8	16
·	A	17
9	9	18
5	5	19
7	7	20
=	–	21
stop	0	22
#	3	23
3	3	24
X	·	25
rcl	5	26
)	6	27
÷	G	28
stop	0	29
#	3	30
2	2	31
+	E	32
rcl	5	33
=	–	34
stop	0	35

CENTRE OF GRAVITY AND RADIUS OF GYRATION

Toroid (rectangular section)



For notation see page 28

Volume = $2\pi atl$

$$k_{xx}^2 = a^2 + \frac{t^2}{4}$$

$$k_{yy}^2 = \frac{a^2}{2} + \frac{t^2}{8} + \frac{l^2}{12}$$

Execution:

a / RUN / t / RUN / k_{xx}^2 / l / RUN / k_{yy}^2

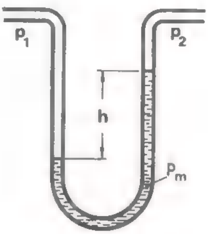
Post-execution (to find volume):

▲▼ / rcl / X / 6·2831852 / = / volume

sto	2	00
X	·	01
+	E	02
(	6	03
stop	0	04
X	·	05
▼	A	06
MEx	5	07
=	–	08
▼	A	09
MEx	5	10
÷	G	11
#	3	12
2	2	13
X	·	14
)	6	15
+	E	16
(	6	17
stop	0	18
X	·	19
▼	A	20
MEx	5	21
=	–	22
▼	A	23
MEx	5	24
X	·	25
÷	G	26
#	3	27
6	6	28
=	–	29
)	6	30
÷	G	31
#	3	32
2	2	33
=	–	34
stop	0	35

PRESSURE FLOW MEASUREMENT

Manometer



pressure difference $p_1 - p_2 = gh(\rho_m - \rho)$

Execution:

ρ_m / RUN / ρ / RUN / h / RUN / pressure difference

In S.I. units; g taken as $9{\cdot}81\ ms^{-2}$.

–	F	00
stop	0	01
X	·	02
stop	0	03
X	·	04
#	3	05
9	9	06
·	A	07
8	8	08
1	1	09
=	–	10
stop	0	11
▼	A	12
goto	2	13
0	0	14
0	0	15
		16
		17
		18
		19
		20
		21
		22
		23
		24
		25
		26
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		33
		34
		35

FLOW RATES

Pitot static tube

u = velocity of fluid
P = total pressure
p = static pressure
ρ = density

$$u = \sqrt{\frac{2(P - p)}{\rho}}$$

Execution:

P / RUN / p / RUN / ρ / RUN / u

–	F	00
stop	0	01
÷	G	02
stop	0	03
+	E	04
=	–	05
$\sqrt{x}$	1	06
stop	0	07
▼	A	08
goto	2	09
0	0	10
0	0	11
		12
		13
		14
		15
		16
		17
		18
		19
		20
		21
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		33
		34
		35

FLOW RATES

Sharp edged orifice

A = area
Q = volume flow rate
C_d = discharge coefficient

$$Q = AC_d\sqrt{2gh}$$

Execution:

h / RUN / A / RUN / C_d / RUN / [illegible]

In S.I. units; g taken as $9{\cdot}81\,ms^{-2}$.

X	·	00
#	3	01
1	1	02
9	9	03
·	A	04
6	6	05
2	2	06
=	–	07
$\sqrt{x}$	1	08
X	·	09
stop	0	10
X	·	11
stop	0	12
=	–	13
stop	0	14
▼	A	15
goto	2	16
0	0	17
0	0	18
		19
		20
		21
		22
		23
		24
		25
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		29
		30
		31
		32
		33
		34
		35

FLOW RATES

Venturi

Subscript 1 refers to tube
Subscript 2 refers to throat
p = static pressure
a = area
u = velocity of fluid
ρ = density

$$u = \sqrt{\frac{2(p_1 - p_2)}{\rho\left[\left(\frac{a_1}{a_2}\right)^2 - 1\right]}}$$

Execution:

a_1 / RUN / a_2 / RUN / ρ / RUN / p_1 / RUN / p_2 / RUN / u

Restrictions:

$a_1 > a_2$, $p_1 > p_2$ or

$a_1 < a_2$, $p_1 < p_2$

÷	G	00
stop	0	01
X	·	02
–	F	03
#	3	04
1	1	05
X	·	06
stop	0	07
÷	G	08
X	·	09
(	6	10
stop	0	11
–	F	12
stop	0	13
+	E	14
)	6	15
=	–	16
$\sqrt{x}$	1	17
stop	0	18
▼	A	19
goto	2	20
0	0	21
0	0	22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

PIPE FLOW

X	·	00
X	·	01
stop	0	02
X	·	03
stop	0	04
X	·	05
stop	0	06
÷	G	07
stop	0	08
+	E	09
=	–	10
stop	0	11
▼	A	12
goto	2	13
0	0	14
0	0	15
		16
		17
		18
		19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

L = length
D = diameter
C_f = skin inertia coefficient
ρ = density
U_m = mean velocity

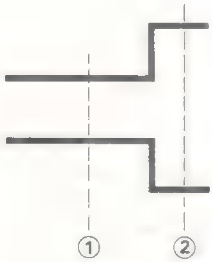
$$\text{pressure drop} = 2\frac{L}{D} C_f \rho U_m^2$$

Execution:

U_m / RUN / ρ / RUN / C_f / RUN / L / RUN / D / RUN / pressure drop

PIPE FLOW

Sudden expansion



Head loss = $\frac{(u_1 - u_2)^2}{2g}$ (i)

$\Delta h = \frac{u_1^2}{2g}\left(1 - \frac{A_1}{A_2}\right)^2$ (ii)

Execution:

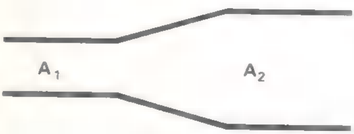
(i) u_1 / RUN / u_2 / RUN / head loss
(post execution with / RUN / RUN / before entering new data)

(ii) u_1 / RUN / RUN / A_1 / RUN / A_2 / RUN / head loss

In S.I. units; g taken as 9·81ms⁻².

—	F	00
stop	0	01
X	·	02
÷	G	03
#	3	04
1	1	05
9	9	06
·	A	07
6	6	08
2	2	09
X	·	10
(	6	11
stop	0	12
÷	G	13
stop	0	14
—	F	15
#	3	16
1	1	17
X	·	18
)	6	19
=	—	20
stop	0	21
▼	A	22
goto	2	23
0	0	24
0	0	25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

IDEAL PRESSURE RISE DIFFUSER



A = area

$$\Delta p = \frac{\rho u_1^2}{2}\left[1 - \left(\frac{A_1}{A_2}\right)^2\right]$$

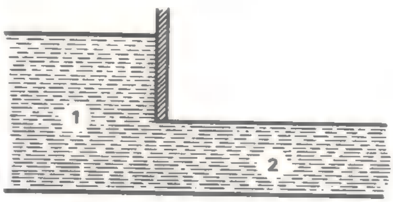
Execution:

A_1 / RUN / A_2/ RUN / u_1 / RUN / ρ / RUN / Δp

($A_2 > A_1$ for +ve Δp)

÷	G	00
stop	0	01
X	·	02
—	F	03
#	3	04
1	1	05
—	F	06
X	·	07
(	6	08
stop	0	09
X	·	10
)	6	11
X	·	12
stop	0	13
÷	G	14
#	3	15
2	2	16
=	—	17
stop	0	18
▼	A	19
goto	2	20
0	0	21
0	0	22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

SLUICE GATE



$$F_2^2 = \frac{u_2^2}{gh_2} \qquad \text{(i)}$$

$$= \frac{2h_1^2}{h_2(h_1 + h_2)} \qquad \text{(ii)}$$

Execution:

(i) u_2 / RUN / h_2 / RUN / F_2^2

In S.I. units; g taken as $9{\cdot}81 ms^{-2}$.

X	·	00
÷	G	01
stop	0	02
÷	G	03
#	3	04
9	9	05
·	A	06
8	8	07
1	1	08
=	–	09
stop	0	10
▼	A	11
goto	2	12
0	0	13
0	0	14
		15
		16
		17
		18
		19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

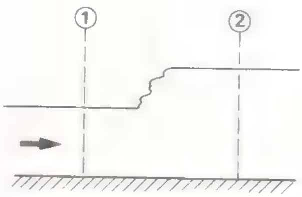
Sluice gate *(cont.)*

(ii) h_2 / RUN / h_1 / RUN / $F_2{}^2$

÷	G	00
stop	0	01
+	E	02
(	6	03
X	·	04
)	6	05
÷	G	06
+	E	07
=	—	08
▼	A	09
goto	2	10
0	0	11
0	0	12
		13
		14
		15
		16
		17
		18
		19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

HYDRAULIC JUMP

÷	G	00
stop	0	01
+	E	02
(	6	03
X	·	04
)	6	05
÷	G	06
#	3	07
2	2	08
=	–	09
stop	0	10
▼	A	11
goto	2	12
0	0	13
0	0	14
		15
		16
		17
		18
		19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35



$$F_1^2 = \frac{h_2(h_1 + h_2)}{2h_1^2} \qquad \text{(i)}$$

$$F_2^2 = \frac{h_1(h_1 + h_2)}{2h_2^2} \qquad \text{(ii)}$$

Execution:

(i) h_2 / RUN / h_1 / RUN / F_1^2

(ii) h_1 / RUN / h_2 / RUN / F_2^2

COMPRESSIBLE FLOW

Perfect gas relationships:

M = mach number

γ = ratio of specific heats = 1·405 for dry air

$$\frac{T}{T_o} = \left(1 - \frac{(\gamma - 1)\,M^2}{2}\right)$$

$$\frac{P}{P_o} = \left(1 - \frac{(\gamma - 1)\,M^2}{2}\right)^{\frac{\gamma}{\gamma - 1}}$$

$$\frac{\rho}{\rho_o} = \left(1 - \frac{(\gamma - 1)\,M^2}{2}\right)^{\frac{1}{\gamma - 1}}$$

Execution:

M / RUN / γ / RUN / $\frac{T}{T_o}$ / RUN / $\frac{P}{P_o}$ / RUN / $\frac{\rho}{\rho_o}$

X	·	00
–	F	01
(	6	02
X	·	03
stop	0	04
sto	2	05
)	6	06
÷	G	07
#	3	08
2	2	09
+	E	10
#	3	11
1	1	12
=	–	13
stop	0	14
ln	4	15
÷	G	16
(	6	17
rcl	5	18
–	F	19
#	3	20
1	1	21
=	–	22
)	6	23
X	·	24
▼	A	25
MEx	5	26
=	–	27
▼	A	28
e^x	4	29
stop	0	30
rcl	5	31
=	–	32
▼	A	33
e^x	4	34
stop	0	35

THERMODYNAMICS

Polytropic process

p = pressure
v = volume
n = index
T = absolute temperature
R = gas constant

pv^n = constant

To find index or final pressure or volume

(i) $p_2 = p_1 \left(\frac{v_1}{v_2}\right)^n$

(ii) $v_2 = v_1 \left(\frac{p_1}{p_2}\right)^{\frac{1}{n}}$

(iii) $n = -\frac{\log\left(\frac{p_2}{p_1}\right)}{\log\left(\frac{v_2}{v_1}\right)}$

Execution:

(i) n / RUN / v_1 / RUN / v_2 / RUN / p_1 / RUN / p_2

(ii) n / ÷ / RUN / p_1 / RUN / p_2 / RUN / v_1 / RUN / v_2

(iii) / ▲▼ / ▲▼ / goto / 1 / 9 / p_1 / RUN / p_2 / RUN / v_1 / RUN / v_2 / RUN / n

X	·	00
(	6	01
stop	0	02
÷	G	03
stop	0	04
=	–	05
ln	4	06
)	6	07
=	–	08
▼	A	09
e^x	4	10
X	·	11
stop	0	12
=	–	13
stop	0	14
▼	A	15
goto	2	16
0	0	17
0	0	18
÷	G	19
stop	0	20
=	–	21
ln	4	22
÷	G	23
(	6	24
stop	0	25
÷	G	26
stop	0	27
=	–	28
ln	4	29
)	6	30
–	F	31
=	–	32
stop	0	33
=	–	34
=	–	35

THERMODYNAMICS

Polytropic process

To find work

$$\text{work} = \frac{p_2 v_2 - p_1 v_1}{1 - n} \qquad \text{(i)}$$

$$= \frac{R(T_2 - T_1)}{1 - n} \qquad \text{(ii)}$$

for a perfect gas

Execution:

(i) p_1 /RUN / v_1 / RUN / p_2 / RUN / v_2 / RUN / n / RUN / work

(ii) R / RUN / T_1 / RUN / RUN / T_2 / RUN / n / RUN / work

sto	2	00
×	·	01
stop	0	02
–	F	03
(	6	04
rcl	5	05
stop	0	06
×	·	07
stop	0	08
)	6	09
÷	G	10
(	6	11
#	3	12
1	1	13
–	F	14
stop	0	15
)	6	16
–	F	17
=	–	18
stop	0	19
▼	A	20
goto	2	21
0	0	22
0	0	23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

HEAT CONDUCTION SHAPE FACTORS

Cylinder

r_i = inside radius
r_o = outside radius
L = length
F = shape factor

$$F = \frac{2\pi L}{\ln\left(\frac{r_o}{r_i}\right)}$$

Execution:

r_o / RUN / r_i / RUN / L / RUN / F

÷	G	00
stop	0	01
=	–	02
ln	4	03
÷	G	04
X	·	05
stop	0	06
X	·	07
#	3	08
3	3	09
6	6	10
0	0	11
=	–	12
▼	A	13
D→R	3	14
stop	0	15
▼	A	16
goto	2	17
0	0	18
0	0	19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

HEAT CONDUCTION SHAPE FACTORS

Sphere

r_i = inside radius
r_o = outside radius

$$F = \frac{4\pi r_o r_i}{r_o - r_i}$$

Execution:

r_i / RUN / r_o / RUN / F

÷	G	00
–	F	01
(	6	02
stop	0	03
÷	G	04
)	6	05
÷	G	06
X	·	07
#	3	08
7	7	09
2	2	10
0	0	11
=	–	12
▼	A	13
D→R	3	14
stop	0	15
▼	A	16
goto	2	17
0	0	18
0	0	19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

HEAT CONDUCTION SHAPE FACTORS

Horizontal disc

r = radius
D = centre line depth

$$F = \frac{2{\cdot}22\,r}{1 - \dfrac{r}{2{\cdot}83D}}$$

Execution:

r / RUN / D / RUN / F

sto	2	00
÷	G	01
stop	0	02
÷	G	03
#	3	04
2	2	05
·	A	06
8	8	07
3	3	08
–	F	09
#	3	10
1	1	11
–	F	12
÷	G	13
X	·	14
rcl	5	15
X	·	16
#	3	17
2	2	18
·	A	19
2	2	20
2	2	21
=	–	22
stop	0	23
▼	A	24
goto	2	25
0	0	26
0	0	27
		28
		29
		30
		31
		32
		33
		34
		35

HEAT CONDUCTION SHAPE FACTOR

Buried sphere

r = radius
D = centre line depth

$$F = \frac{\pi r}{1 - \frac{r}{2D}}$$

Execution:

r / RUN / D / RUN / F

sto	2	00
÷	G	01
stop	0	02
–	F	03
#	3	04
2	2	05
–	F	06
÷	G	07
X	·	08
rcl	5	09
X	·	10
#	3	11
3	3	12
6	6	13
0	0	14
=	–	15
▼	A	16
D→R	3	17
stop	0	18
▼	A	19
goto	2	20
0	0	21
0	0	22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

ACOUSTICS

Adding sound levels (and weighted sound levels) in dB (+ hourly average of sound level) (Log. r.m.s. addition)

$$L_n = 10 \log_{10} \frac{P_n}{P_r} = 4{\cdot}3429448 \ln \frac{P_n}{P_r}$$

where P_r = reference s.p.l. of 2×10^{-5} Nm^{-2}

Definitions:

Noise level addition operator $\oplus$

$$L_m \oplus L_n = 4{\cdot}34294 \ln \left[\exp\left(\frac{L_m}{4{\cdot}34294}\right) + \exp\left(\frac{L_n}{4{\cdot}34294}\right) \right]$$

Noise level subtraction operator $\ominus$

$$L_m \ominus L_n = 4{\cdot}34294 \ln \left[\exp\left(\frac{L_m}{4{\cdot}34294}\right) - \exp\left(\frac{L_n}{4{\cdot}34294}\right) \right]$$

Weighting by time operator $\otimes$

$$L_n \otimes t_n = 4{\cdot}34294 \ln \left[t_n \exp\left(\frac{L_n}{4{\cdot}34294}\right) \right]$$

Averaging over time

$$L_{av} = 4{\cdot}34294 \ln \left[\frac{1}{t} \sum_{k=1}^{n} t_k \exp\left(\frac{L_k}{4{\cdot}34294}\right) \right]$$

$t = t_1 + t_2 + \cdots + t_n$

Weighting table ('A' weighting)

f(Hz)	W_f(dB)	f(kHz)	W_f(dB)
31·5	39	1	0
63	26	2	1
125	16	4	1
250	10	8	1
500	3		

÷	G	00
#	3	01
8	8	02
·	A	03
6	6	04
8	8	05
5	5	06
8	8	07
9	9	08
=	–	09
▼	A	10
e^x	4	11
X	·	12
stop	0	13
+	E	14
rcl	5	15
=	–	16
sto	2	17
$\sqrt{x}$	1	18
ln	4	19
X	·	20
#	3	21
8	8	22
·	A	23
6	6	24
8	8	25
5	5	26
8	8	27
9	9	28
=	–	29
stop	0	30
▼	A	31
goto	2	32
0	0	33
0	0	34
		35

Pre-execution:

/ ▲▼ / ▲▼ / goto / 0 / 0 / C/CE / ▲▼ / sto /
to clear memory

Execution:

(i) Adding noise/sound levels:

L_1 / RUN / RUN / L_2 / RUN / RUN / $L_1 \oplus L_2$ / L_3 / RUN /
RUN / $L_1 \oplus L_2 \oplus L_3 \cdots$

(ii) Subtracting noise levels:

L_1 / RUN / RUN / L_2 / RUN / – / RUN / $L_1 \in L_2$
(add or subtract levels at will)

(iii) Adding and weighting noise levels:

L_1 / – / W_1 / RUN / RUN / $L_1 - W_1$ / L_2 / – / W_2 / RUN /
RUN / $(L_1 - W_1) \oplus (L_2 - W_2) \cdots$ (see table for W_f)

Post execution:

/ ▲▼ / ▲▼ / goto / 1 / 4 / C/CE / ▲▼ / ▲▼ / MEx / ÷ / n /
RUN / $L_{weighted}$

where n = no. of levels entered.

(iv) Time averaged noise levels:

L_1 / RUN / X / t_1 / RUN / $L_1 \otimes t_1$ / L_2 / RUN / X / t_2 / RUN /
$(L_1 \otimes t_1) \oplus (L_2 \otimes t_2) \cdots$

Post execution:

/ ▲▼ / ▲▼ / goto / 1 / 4 / C/CE / ▲▼ / ▲▼ / MEx / ÷ / t /
RUN / L_{av}

(v) Hourly averaged noise level:

Add 24 hourly levels using (i) then post-execution

Post execution:

/ ▲▼ / ▲▼ / goto / 1 / 4 / C/CE / ▲▼ / ▲▼ / MEx / ÷ / 24 /
RUN / L_{av}

DECIBEL CONVERSION

$$A_{dB} = 10 \log_{10} \frac{P_2}{P_1} = 20 \log_{10} \frac{E_2}{E_1}$$

$$= 20 \log_{10} \frac{I_2}{I_1}$$

$$P_2 = P_1 \operatorname{antilog}_{10} \frac{AdB}{10}$$

$$E_2 = E_1 \operatorname{antilog}_{10} \frac{AdB}{20}$$

$$I_2 = I_1 \operatorname{antilog}_{10} \frac{AdB}{20}$$

Neper conversion:

$$A_n = \frac{1}{2} \ln \frac{P_2}{P_1} = \ln \frac{E_2}{E_1} = \ln \frac{I_2}{I_1}$$

$$P_2 = P_1 \exp 2A_n$$

$$E_2 = E_1 \exp A_n$$

$$I_2 = I_1 \exp A_n$$

Ratio to dB or nepers:

Execution:

P_2 / ÷ / P_1 / = / ▲▼ / $\sqrt{x}$ /
or E_2 / ÷ / E_1 / = /
or I_2 / ÷ / I_1 / = /
} r / RUN / A_n / RUN / A_{dB}

ln	4	00
stop	0	01
X	·	02
#	3	03
8	8	04
·	A	05
6	6	06
8	8	07
5	5	08
8	8	09
9	9	10
=	–	11
stop	0	12
▼	A	13
goto	2	14
0	0	15
0	0	16
÷	G	17
#	3	18
8	8	19
·	A	20
6	6	21
8	8	22
5	5	23
8	8	24
9	9	25
=	–	26
stop	0	27
▼	A	28
e^x	4	29
X	·	30
stop	0	31
▼	A	32
goto	2	33
1	1	34
7	7	35

dB or nepers to ratio:

Pre-execution:

dB to ratio:	▲▼ / ▲▼ / goto / 1 / 7 / first time only
nepers to ratio:	▲▼ / ▲▼ / goto / 2 / 8 / every time

Execution:

dB to ratio:

$$A_{dB}\ /\ \mathrm{RUN}\ /\ A_n\ /\ \mathrm{RUN}\ /\ r \begin{cases} & /\ \times\ /\ P_1\ /\ =\ /\ P_2 \\ \textit{or} & /\ E_1\ /\ =\ /\ E_2 \\ \textit{or} & /\ I_1\ /\ =\ /\ I_2 \\ \textit{or} & /\ =\ /\ r^2 \end{cases}$$

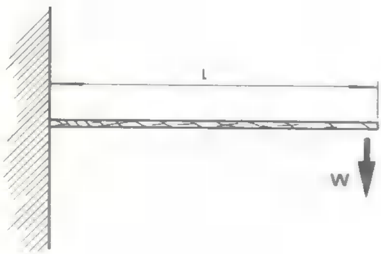
Always use / = / even if no other result is required.

nepers to ratio:

A_n / RUN / r and continue with alternatives as above.

BEAM BENDING

Beam with one fixed end and load W at free end



end slope = $\dfrac{W\ell^2}{2EI}$

end deflection = $\dfrac{W\ell^3}{3EI}$

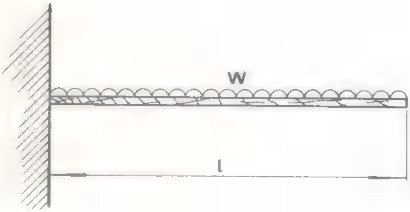
Execution:

ℓ / RUN / W / RUN / E / RUN / I / RUN / slope / RUN / deflection

sto	2	00
X	·	01
X	·	02
stop	0	03
÷	G	04
stop	0	05
÷	G	06
stop	0	07
÷	G	08
#	3	09
2	2	10
÷	G	11
stop	0	12
#	3	13
1	1	14
·	A	15
5	5	16
X	·	17
rcl	5	18
=	–	19
stop	0	20
▼	A	21
goto	2	22
0	0	23
0	0	24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

BEAM BENDING

Beam with one fixed end and distributed loading W



end slope = $\dfrac{W\ell^2}{6EI}$

end deflection = $\dfrac{W\ell^3}{8EI}$

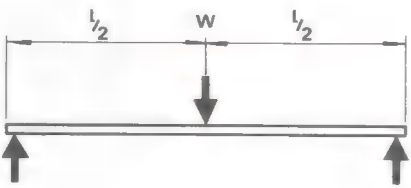
Execution:

ℓ / RUN / W / RUN / E / RUN / I / RUN / slope / RUN / deflection

sto	2	00
X	·	01
X	·	02
stop	0	03
÷	G	04
stop	0	05
÷	G	06
stop	0	07
÷	G	08
#	3	09
6	6	10
X	·	11
stop	0	12
#	3	13
·	A	14
7	7	15
5	5	16
X	·	17
rcl	5	18
=	–	19
stop	0	20
▼	A	21
goto	2	22
0	0	23
0	0	24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

BEAM BENDING

Simply supported beam with central load W



end slope = $\dfrac{W\ell^2}{16EI}$

central deflection = $\dfrac{W\ell^3}{48EI}$

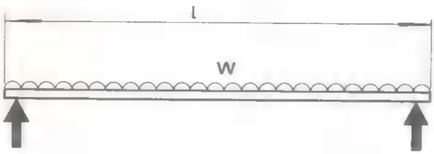
Execution:

ℓ / RUN / W / RUN / E / RUN / I / RUN /
end slope / RUN / central deflection

sto	2	00
X	·	01
X	·	02
stop	0	03
÷	G	04
stop	0	05
÷	G	06
stop	0	07
÷	G	08
#	3	09
1	1	10
6	6	11
÷	G	12
stop	0	13
#	3	14
3	3	15
X	·	16
rcl	5	17
=	–	18
stop	0	19
▼	A	20
goto	2	21
0	0	22
0	0	23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

BEAM BENDING

Simply supported beam with distributed loading W



end slope = $\frac{W\ell^2}{24EI}$

central deflection = $\frac{5W\ell^3}{384EI}$

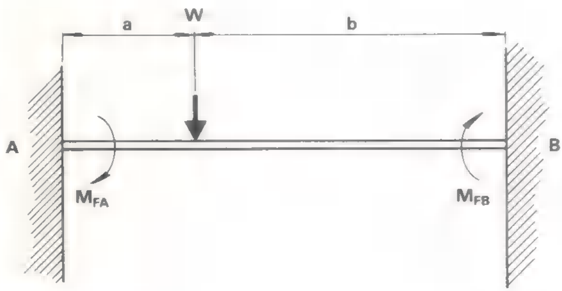
Execution:

ℓ / RUN / W / RUN / E / RUN / I / RUN / end slope / RUN / central deflection

sto	2	00
X	·	01
X	·	02
stop	0	03
÷	G	04
stop	0	05
÷	G	06
stop	0	07
÷	G	08
#	3	09
2	2	10
4	4	11
÷	G	12
stop	0	13
#	3	14
3	3	15
·	A	16
2	2	17
X	·	18
rcl	5	19
=	—	20
stop	0	21
▼	A	22
goto	2	23
0	0	24
0	0	25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

BEAM BENDING

Beam fixed at both ends with load W at a distance from end A



$$M_{FA} = \frac{Wb^2 a}{\ell^2}$$

$$M_{FB} = \frac{Wa^2 b}{\ell^2}$$

$\ell = a + b$

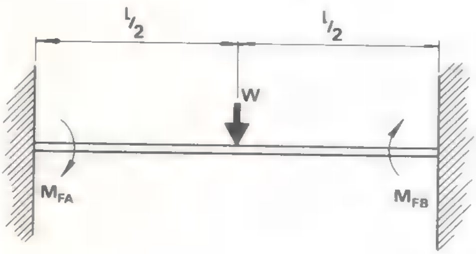
Execution:

b / RUN / a / RUN / W / RUN / ℓ / RUN / M_{FA} / RUN / M_{FB}

sto	2	00
X	·	01
X	·	02
rcl	5	03
X	·	04
(	6	05
stop	0	06
÷	G	07
rcl	5	08
)	6	09
sto	2	10
X	·	11
stop	0	12
÷	G	13
(	6	14
stop	0	15
X	·	16
)	6	17
–	F	18
X	·	19
stop	0	20
rcl	5	21
–	F	22
=	–	23
stop	0	24
▼	A	25
goto	2	26
0	0	27
0	0	28
		29
		30
		31
		32
		33
		34
		35

BEAM BENDING

Beam with two fixed ends and central loading W



Fixed end moments

$$M_{FA} = -\frac{W\ell}{8}$$

$$M_{FB} = \frac{W\ell}{8}$$

Central deflection

$$d = \frac{W\ell^3}{192EI}$$

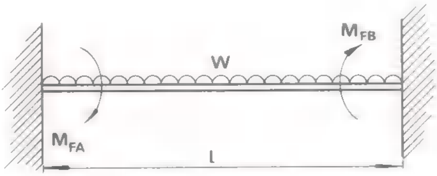
Execution:

W / RUN / ℓ / RUN / E / RUN / I / RUN / M_{FA} / RUN / M_{FB} / RUN / d

÷	G	00
#	3	01
8	8	02
X	·	03
stop	0	04
sto	2	05
X	·	06
(	6	07
▼	A	08
MEx	5	09
X	·	10
)	6	11
÷	G	12
#	3	13
2	2	14
4	4	15
÷	G	16
stop	0	17
÷	G	18
stop	0	19
=	–	20
▼	A	21
MEx	5	22
–	F	23
–	F	24
stop	0	25
=	–	26
stop	0	27
rcl	5	28
stop	0	29
▼	A	30
goto	2	31
0	0	32
0	0	33
		34
		35

BEAM BENDING

Beam between two fixed ends with evenly distributed total load W



Fixed end moments

$$M_{FA} = -\frac{W\ell}{12}$$

$$M_{FB} = \frac{W\ell}{12}$$

Central deflection

$$d = \frac{W\ell^3}{384EI}$$

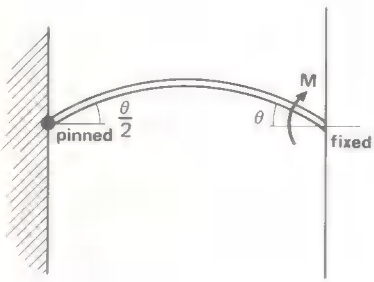
Execution:

W / RUN / ℓ / RUN / E / RUN / I / RUN / M_{FA} / RUN / M_{FB} / RUN /

÷	G	00
#	3	01
1	1	02
2	2	03
X	·	04
stop	0	05
sto	2	06
X	·	07
(	6	08
▼	A	09
MEx	5	10
X	·	11
)	6	12
÷	G	13
#	3	14
3	3	15
2	2	16
÷	G	17
stop	0	18
÷	G	19
stop	0	20
=	–	21
▼	A	22
MEx	5	23
–	F	24
–	F	25
stop	0	26
=	–	27
stop	0	28
rcl	5	29
stop	0	30
▼	A	31
goto	2	32
0	0	33
0	0	34
		35

BEAM BENDING

Beam with one fixed end, one pinned end.
Effect of rotation at fixed end.



M = applied bending moment

$$\text{end slope} = \frac{M\ell}{3EI}$$

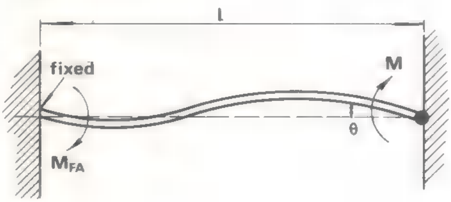
Execution:

M / RUN / ℓ / RUN / E / RUN / I / RUN / end slope

X	·	00
stop	0	01
÷	G	02
stop	0	03
÷	G	04
stop	0	05
÷	G	06
#	3	07
3	3	08
=	—	09
stop	0	10
▼	A	11
goto	2	12
0	0	13
0	0	14
		15
		16
		17
		18
		19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

BEAM BENDING

Beam with [illegible] fixed end and one pinned end – effect of rotation at pinned end



Moment at fixed end A, = $M_{FA} = \dfrac{M}{2}$

end slope $\theta = \dfrac{M\ell}{4EI}$

Execution:

M / RUN / ℓ / RUN / E / RUN / I / RUN / end slope

X	·	00
stop	0	01
÷	G	02
stop	0	03
÷	G	04
stop	0	05
÷	G	06
#	3	07
4	4	08
=	–	09
stop	0	10
▼	A	11
goto	2	12
0	0	13
0	0	14
		15
		16
		17
		18
		19
		20
		21
		22
		23
		24
		25
		26
		27
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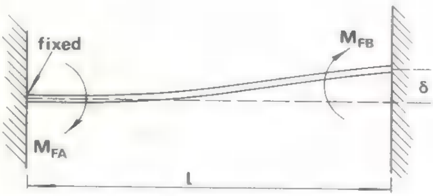
		29
		30
		31
		32
		33
		34
		35

BEAM BENDING

Effect of end displacement on beam fixed at both ends



Moments at fixed ends due to displacement δ

$$M_{FA} = M_{FB} = \frac{+6EI\delta}{\ell^2}$$

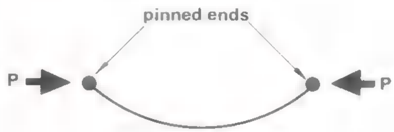
Execution:

E / RUN / I / RUN / δ / RUN / ℓ / RUN / M_{FA}

X	·	00
stop	0	01
X	·	02
stop	0	03
X	·	04
stop	0	05
X	·	06
#	3	07
6	6	08
÷	G	09
(	6	10
stop	0	11
X	·	12
)	6	13
=	–	14
stop	0	15
▼	A	16
goto	2	17
0	0	18
0	0	19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

STRUTS

Critical load – strut with two pinned ends



$$P_{crit.} = \text{critical load} = \frac{\pi^2 E I}{\ell^2}$$

Execution:

ℓ / RUN / E / RUN / I / RUN / P_{crit}

÷	G	00
#	3	01
3	3	02
·	A	03
1	1	04
4	4	05
1	1	06
6	6	07
÷	G	08
X	·	09
X	·	10
stop	0	11
X	·	12
stop	0	13
=	–	14
stop	0	15
▼	A	16
goto	2	17
0	0	18
0	0	19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

STRUTS

Critical load for strut fixed at one end, pinned at other end

$$P_{crit.} = \frac{2\pi^2 EI}{\ell^2}$$

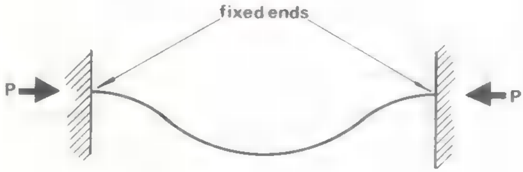
Execution:

ℓ / RUN / E / RUN / I / RUN / P_{crit}

÷	G	00
#	3	01
3	3	02
·	A	03
1	1	04
4	4	05
1	1	06
5	5	07
9	9	08
2	2	09
6	6	10
÷	G	11
X	·	12
+	E	13
X	·	14
stop	0	15
X	·	16
stop	0	17
=	—	18
stop	0	19
▼	A	20
goto	2	21
0	0	22
0	0	23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

STRUTS

Strut with two fixed ends



$$P_{crit.} = \frac{4\pi^2 EI}{\ell^2}$$

Execution:

ℓ / RUN / E / RUN / I / RUN / $P_{crit.}$

÷	G	00
#	3	01
6	6	02
·	A	03
2	2	04
8	8	05
3	3	06
2	2	07
÷	G	08
X	·	09
X	·	10
stop	0	11
X	·	12
stop	0	13
=	–	14
stop	0	15
▼	A	16
goto	2	17
0	0	18
0	0	19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

STRUTS

Critical load for strut with [redacted] fixed end and one free end

$$P_{crit.} = \frac{EI\pi^2}{(2\ell)^2}$$

Execution:

ℓ / RUN / E / RUN / I / RUN / $P_{crit.}$

÷	G	00
#	3	01
9	9	02
0	0	03
÷	G	04
=	–	05
▼	A	06
D→R	3	07
X	·	08
X	·	09
stop	0	10
X	·	11
stop	0	12
=	–	13
stop	0	14
▼	A	15
goto	2	16
0	0	17
0	0	18
		19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

TORSION OF THIN WALLED TUBE

X	·	00
(	6	01
X	·	02
)	6	03
X	·	04
#	3	05
3	3	06
6	6	07
0	0	08
X	·	09
stop	0	10
X	·	11
stop	0	12
X	·	13
stop	0	14
=	—	15
▼	A	16
D→R	3	17
stop	0	18
▼	A	19
goto	2	20
0	0	21
0	0	22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

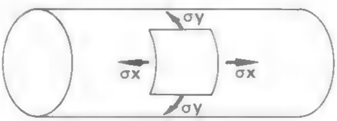
$$\text{Torque} = 2\pi r^3 t\, G \frac{\theta}{L}$$

$$\frac{\theta}{L} = \text{twist per unit length} = \frac{\text{angular deflection}}{\text{length}}$$

Execution:

r / RUN / t / RUN / G / RUN / $\frac{\theta}{L}$ / RUN / torque

CYLINDRICAL PRESSURE VESSEL



Longitudinal stress $\sigma_x = \dfrac{pd}{4t}$

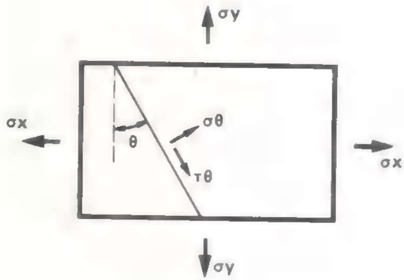
Hoop stress $\sigma_y = \dfrac{pd}{2t}$

Execution:

p / RUN / d / RUN / t / RUN / σ_x / RUN / σ_y

X	·	00
stop	0	01
÷	G	02
stop	0	03
÷	G	04
#	3	05
4	4	06
+	E	07
stop	0	08
=	–	09
stop	0	10
▼	A	11
goto	2	12
0	0	13
0	0	14
		15
		16
		17
		18
		19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

COMPLEX STRESSES



$$\sigma_\theta = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2}\cos 2\theta$$

$$\tau_\theta = \frac{\sigma_x - \sigma_y}{2}\sin 2\theta$$

Execution:

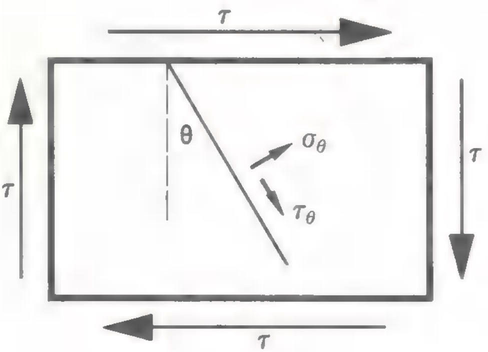
σ_x / + / σ_y / RUN / θ / RUN / σ_θ / θ / ▲▼ / ▲▼ / MEx/ RUN / τ_θ

For angle θ in degrees use / ▲▼ / ▲▼ / D→R / after entering θ each time.

For negative θ use / – / = / after third / RUN / to give correct sign of τ_θ.

sto	2	00
÷	G	01
#	3	02
2	2	03
+	E	04
(	6	05
–	F	06
rcl	5	07
=	–	08
sto	2	09
stop	0	10
sin	7	11
X	·	12
+	E	13
–	F	14
+	E	15
#	3	16
1	1	17
X	·	18
rcl	5	19
)	6	20
=	–	21
stop	0	22
X	·	23
(	6	24
rcl	5	25
sin	7	26
)	6	27
X	·	28
(	6	29
rcl	5	30
cos	8	31
)	6	32
+	E	33
=	–	34
stop	0	35

COMPLEX STRESSES



$\sigma_\theta = \tau \sin 2\theta$
$\tau_\theta = -\tau \cos 2\theta$

Execution:

θ / RUN / τ / RUN / τ_θ / RUN / σ_θ

For θ in degrees insert / ▼ / D→R / at start of program or use / ▲▼ / ▲▼ / D→R / after entering θ.

For negative θ, use / – / = / after third / RUN / to give correct sign of σ_θ.

sin	7	00
X	·	01
+	E	02
–	F	03
+	E	04
#	3	05
1	1	06
=	–	07
sto	2	08
stop	0	09
X	·	10
(	6	11
X	·	12
rcl	5	13
–	F	14
=	–	15
stop	0	16
rcl	5	17
X	·	18
–	F	19
+	E	20
#	3	21
1	1	22
=	–	23
$\sqrt{x}$	1	24
)	6	25
=	–	26
stop	0	27
▼	A	28
goto	2	29
0	0	30
0	0	31
		32
		33
		34
		35

ELASTIC STRAIN ENERGY

X	·	00
÷	G	01
#	3	02
2	2	03
÷	G	04
stop	0	05
=	–	06
stop	0	07
▼	A	08
goto	2	09
0	0	10
0	0	11
		12
		13
		14
		15
		16
		17
		18
		19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

Elastic strain energy:

(i) In tension $\dfrac{\sigma^2}{2E}$

(ii) In torsion $\dfrac{\tau^2}{2G}$

Execution:

(i) σ / RUN / E / RUN / energy

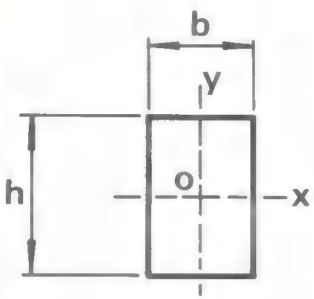
(ii) τ / RUN / G / RUN / energy

ELASTIC AND PLASTIC SECTIONAL MODULI

Z_e = elastic section modulus
Z_p = plastic section modulus

shape factor $S = \dfrac{Z_p}{Z_e}$

Solid rectangular section



Axis C_y : $Z_e = \dfrac{b^2 h}{6}$

$Z_p = \dfrac{b^2 h}{4}$

$S = 1{\cdot}5$

Axis C_z : $Z_e = \dfrac{bh^2}{6}$

$Z_p = \dfrac{bh^2}{4}$

$S = 1{\cdot}5$

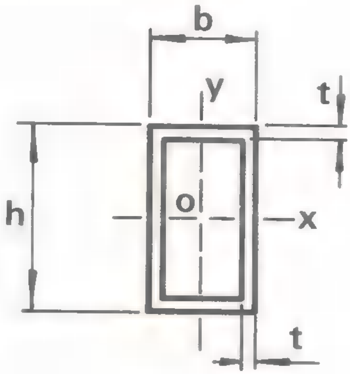
Execution:

b / RUN / h / RUN / Z_e for C_y / RUN / Z_p for C_y / RUN / Z_e for C_z / RUN / Z_p for C_z

sto	2	00
X	·	01
X	·	02
stop	0	03
÷	G	04
#	3	05
6	6	06
X	·	07
stop	0	08
#	3	09
1	1	10
·	A	11
5	5	12
÷	G	13
stop	0	14
rcl	5	15
X	·	16
÷	G	17
rcl	5	18
÷	G	19
#	3	20
·	A	21
3	3	22
7	7	23
5	5	24
X	·	25
stop	0	26
#	3	27
1	1	28
·	A	29
5	5	30
=	–	31
stop	0	32
=	–	33
=	–	34
=	–	35

ELASTIC AND PLASTIC SECTIONAL MODULI

Thin walled rectangular box



(t small compared to h and b)

Axis C_y :

$$Z_e = bt\left(h + \frac{b}{3}\right)$$

$$Z_p = bt\left(h + \frac{b}{2}\right)$$

$$S = \frac{h + \frac{b}{2}}{h + \frac{b}{3}}$$

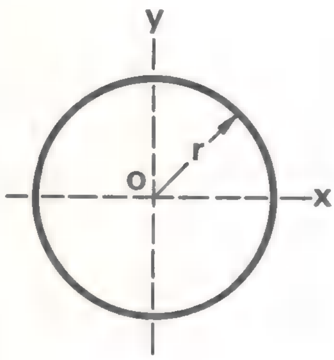
Execution:

h / RUN / b / RUN / t / RUN / Z_e / RUN / Z_p / RUN / S

÷	G	00
stop	0	01
sto	2	02
+	E	03
#	3	04
·	A	05
5	5	06
=	–	07
▼	A	08
MEx	5	09
X	·	10
X	·	11
stop	0	12
X	·	13
(	6	14
#	3	15
6	6	16
÷	G	17
–	F	18
+	E	19
rcl	5	20
÷	G	21
▼	A	22
MEx	5	23
÷	G	24
=	–	25
▼	A	26
MEx	5	27
)	6	28
X	·	29
stop	0	30
rcl	5	31
=	–	32
stop	0	33
rcl	5	34
stop	0	35

ELASTIC AND PLASTIC SECTIONAL MODULI

Solid circular section



$$Z_e = \frac{\pi r^3}{4}$$

$$Z_p = \frac{4r^3}{3}$$

$$S = \frac{16}{3\pi} = 1{\cdot}697653$$

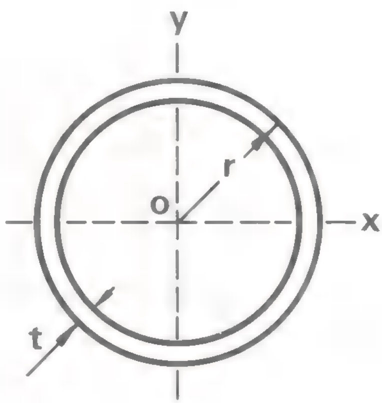
Execution:

r / RUN / Z_e / RUN / Z_p

X	·	00
(	6	01
X	·	02
)	6	03
X	·	04
sto	2	05
#	3	06
4	4	07
5	5	08
=	—	09
▼	A	10
D→R	3	11
stop	0	12
rcl	5	13
÷	G	14
#	3	15
·	A	16
7	7	17
5	5	18
=	—	19
stop	0	20
▼	A	21
goto	2	22
0	0	23
0	0	24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

ELASTIC AND PLASTIC SECTIONAL MODULI

Thin walled circular tube



(t small compared to r)

$Z_e = \pi r^2 t$

$Z_p = 4r^2 t$

$S = \frac{4}{\pi} = 1{\cdot}273240$

Execution:

r / RUN / t / RUN / Z_e / RUN / Z_p

X	·	00
X	·	01
stop	0	02
X	·	03
sto	2	04
#	3	05
1	1	06
8	8	07
0	0	08
=	—	09
▼	A	10
D→R	3	11
stop	0	12
rcl	5	13
+	E	14
+	E	15
=	—	16
stop	0	17
▼	A	18
goto	2	19
0	0	20
0	0	21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

ELASTIC AND PLASTIC SECTIONAL MODULI

Thin I-section

(thickness small compared to overall dimensions)

Axis C_y :

$$Z_e = \frac{b^2 t_f}{3}$$

$$Z_p = \frac{b^2 t_f}{2}$$

$$S = 1{\cdot}5$$

Execution:

b / RUN / t_f / RUN / Z_e / RUN / Z_p

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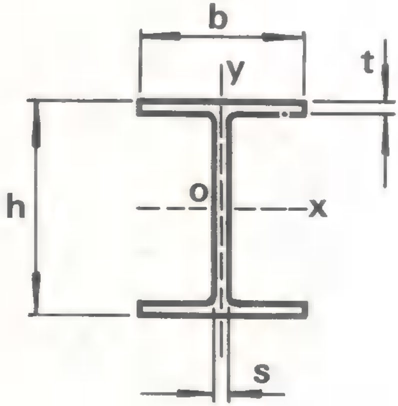
ELASTIC AND PLASTIC SECTIONAL MODULI

Thin I-section



Axis C_z:

$$Z_e = h\left(bt + \frac{hs}{6}\right)$$

$$Z_p = h\left(bt + \frac{hs}{4}\right)$$

$$S = \frac{bt + \frac{hs}{4}}{bt + \frac{hs}{6}}$$

Execution:

h / RUN / S / RUN / b / RUN / t / RUN / Z_e / RUN / Z_p / RUN / S

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